INVESTIGATIONS ON LIGHT AND HEAT, made and published wholly or in part with appropriation from the RUMFORD FUND.

VI.

ON CERTAIN REMARKABLE GROUPS IN THE LOWER SPECTRUM.

BY PROFESSOR S. P. LANGLEY.

Presented Oct. 7, 1878.

IN first studying the diffraction spectrum for the purpose of learning more of the laws governing the selective absorption of the sun's radiant energy, both near its surface and in our own atmosphere, I was much struck, as others have doubtless been, with the remarkable band of lines on the less refrangible side of B. Seen under great dispersion, they were quite unlike any thing I had before observed in the spectrum, while the best maps, I found, gave no adequate idea of their curious structure which possessed to me an unexampled formal regularity. After more study of this portion, I commenced critically to examine the A group, which is nearly the last extremity of the visual spectrum toward the red, and which is so overwhelmed in the diffuse light from brighter portions, that few have, I believe, ever seen it in any detail. I now found another subject of surprise, in the extraordinary resemblance which this group bore to the B group; a resemblance which could not be the result of accident, but which has never been, so far as I can learn, publicly noticed, and of which no published map, I have seen, gives any idea.

It is, of course, known to professional students that in this region such a structure and general resemblance exist; but as I believe that, without special precautions, its extraordinary completeness cannot be made out, it is possible that a very careful drawing, founded wholly on micrometric measurement, of what has never been fully delineated will present some novelty even to the spectroscopist who may not have made this region a special study. To others I may recall —

what any one who has only the slightest acquaintance with the appearance of the whole visible spectrum must have noticed — the entirely casual way in which the lines, all along from red to violet, are juxtaposed. There is no more apparent order in their arrangement than in that of undergrowth in a primitive forest, or of any other disposition of natural objects which we assign to chance. But, if in walking through such a forest, we came to an open space in which the trees were planted two and two, with the most formal regularity, we should hardly doubt that something else than chance had been at work. If we measured the distances and found that these pairs had been set out with such precision that our best instruments could detect no difference between them; if we further found that the spaces between the pairs were themselves not casual, but arranged with exactness in a certain progression, — if we found all this, we should certainly, in the use of ordinary language, say that here Nature had given place to art. If, further on, we saw a second arrangement like the first, which resembled it closer the more we examined, we should find our conclusion for design, if possible, strengthened. It will be seen, I think, that precisely this abrupt transition from confusion to order and symmetry exists in the spectrum, as well as in the singular duplication of the design. What might be called the result of intelligence, if observed in another field of Nature, we must here call conclusive evidence of the existence of law. No accident, but some still hidden law, has regulated, I do not doubt, the curious relations now exhibited. Perhaps, with regard to them, we may be standing ourselves in the same position as those few did who were enabled to contemplate the Fraunhofer lines in the first years of their discovery, and recognize that, though we cannot find their meaning, it promises to be worth knowing.

I had at first meant to present to you some attempts of my own toward a solution. Afterward, considering how little I knew, it seemed to me better to offer nothing in the way of hypothesis now, but for the present to limit myself to furnishing facts, necessary in the creation of any future theory, in the shape of the results of exact measurement. These are given in the accompanying pages, and give sufficiently exact data, I hope, for determining the laws of the numerical harmonies here so plainly latent.

The best drawings of the A lines I have seen are those recently given by Professor C. Piazzi Smythe, Astronomer Royal for Scotland. They were obtained in June, 1877, at Lisbon, whither Professor Smythe made a special voyage to obtain a high sun and clear sky. I

reproduce an exact copy of these with those of Kirchoff. It must, however, be remembered that Kirchoff's and Smythe's drawings, made with prisms, will present a slightly different collocation from those made with a grating. I give also both Kirchoff's and Angstrom's drawings of B, that it may be seen how far justice has been done heretofore to this interesting region in the best maps. In my own, every line is given from repeated micrometric measurement. I have only given part of the A group, therefore, which extends much further, but in so faint a light that I have not felt sure of my measures beyond A_{12}. The relative intensities only are the result of estimate. The scale is double Angstrom's. I have made as yet no studies below the A group, but have discovered an unnoticed analogous group more refrangible than B, which appears in the air-spectrum, and which I do not give, as all these studies belong exclusively to the high sun. From the successive appearances of these three groups, however, I have drawn the inference that the spectrum below A, if ever rendered visible, will probably present a strikingly different type from that above B.

As Captain Abney has lately succeeded in photographing as low as A or lower, it may be proper for me to observe that the general character of the observations here given in detail was, with drawings of A and B, briefly presented by me to the notice of the National Academy, in Washington, in 1877. I have executed this work with apparatus partly due to the Rumford fund, and therefore have delayed a full presentation till I could ask to be allowed the honor of submitting it to the American Academy.

I have been assisted in these measurements by Mr. R. F. Hall and Mr. F. W. Very.

The spectroscope with which these observations have been made is provided with two telescopes of 1.66 inch aperture and of 20.01 inches focal length, which are fixed in the walls of the cylindrical chamber containing the diffraction grating. The angle between the optical axes of the telescopes is fixed here, and it amounts to about 61° 16′. The grating is fastened to a revolving plate. A filar micrometer is attached to the observing telescope. The diffraction grating used is of speculum metal, and is one of the largest made by Mr. Rutherfurd, the actual size of the ruled portion being 1.75 inch square, containing 17,296 lines to the linear inch.

The object of these measurements was to obtain the relative distances between the lines, rather than their absolute wave-length. The distances of the several components from the first line of each group

have been measured with the micrometer. Then, the first line of the group being assigned the value of zero, and the distance from this line to the one numbered 12 being called unity, the relative distances of the intermediate lines are expressed in decimal fractions, which are multiplied by the difference in wave-length of the limiting lines, and the products added to the wave-length of the more refrangible one, which is distinguished in each case by a subscript zero attached to its cognominal letter. It is evident that for these small angles, the largest of which does not exceed 30′, the sine differs so inappreciably from the arc, that the readings of the micrometer may be converted directly into angular measure. The difference between the wave-lengths of the limiting lines of the group has been taken from Angstrom's measurements in the case of the large B group. The line called A_{12} in this paper was not measured by Angstrom. Its wave-length has been approximately determined by the following method: —

The centre of the comb being midway between two known lines of the spectrum, the difference of micrometer readings for these lines was observed. Let the angular distance between them be $2x$. Then from the general formula $nS\lambda = \sin i + \sin r$, where $S = 681$ lines to the millimeter, and n is 1, we have —

$$\left.\begin{array}{l} 1 \times 681 \times \lambda_1 = -\sin i + \sin (r - x) \\ 1 \times 681 \times \lambda_2 = -\sin i + \sin (r + x) \end{array}\right\} \text{ also } r + i = 61^\circ\ 16'$$

Measures taken without disturbance of the micrometer focus gave —

						rev.
Angstrom	(6561.8) C	to	Angstrom	(6716.4)	=	14.942
„	(6716.4)	„	„	(6866.8) B_0	=	14.490
„	(6866.8) B_0	„	„	(6927.8) B_{12}	=	6.087
	A_0	„	„	A_{12}	=	7.727

Substituting these numbers in the appropriate equations, and solving, we have —

$$C \quad 681 \times \overset{\text{m.m.}}{0.000}\ 6561.8 = .44686 = -\sin i_1 + \sin (r_1 - x_1).$$
$$(6716.4) \quad 681 \times 0.000\ 6716.4 = .45739 = -\sin i_1 + \sin (r_1 + x_1).$$
$$i_1 = 15^\circ\ 24'\ 02'' \qquad r_1 = 46^\circ\ 51'\ 58''$$

whence $2x_1 = 51'\ 57'' = \overset{\text{rev.}}{14.942} \therefore \overset{\text{rev.}}{1.} = 3'\ 28''.6$.

We have again —

$$(6716.4)\quad 681 \times \overset{\text{m.m.}}{0.000}\ 6716.4 = .45739 = -\sin i_2 + \sin (r_2 - x_2).$$

$$B_0\quad 681 \times 0.000\ 6866.8 = .46763 = -\sin i_2 + \sin (r_2 + x_2).$$

$$i_2 = 15^\circ\ 02'\ 30'' \qquad r_2 = 46^\circ\ 13'\ 27''$$

whence $2x_2 = 50'\ 54'' = \overset{\text{rev.}}{14.490} \therefore \overset{\text{rev.}}{1.} = 3'\ 30''.8.$

The mean of these values, $3'\ 29''.7$ is taken as the value of one revolution of the micrometer head in arc, at the time the above measures were made on B_{12} and A_{12}, and B_0 to $B_{12} = \overset{\text{rev.}}{6.087} = 21'\ 16''.4$, A_0 to $A_{12} = \overset{\text{rev.}}{7.727} = 27'\ 00''.4$.

$$\text{For } B_0,\ (1)\ 681 \times 6866.8 = .46763 = -\sin i + \sin (r - 10'\ 38''.2)$$

$$\text{,, } B_{12},\ (3)\ 681 \times \lambda\ B_{12} = \qquad = -\sin i + \sin (r + 10'\ 38''.2)$$

$$(2)\quad i + r = 61^\circ\ 16' \qquad i = 14^\circ\ 47'\ 38''$$

Substituting in (3) the values of i and r found by (2), we have $\lambda\ B_{12} = \overset{\text{m.m.}}{0.000}\ 6928.0$. The value of the corresponding line in Angstrom is $\overset{\text{m.m.}}{0.000}\ 6927.8$.

The result of this example showing a sufficiently near approach to accuracy for our purpose, the same method was used for determining the wave-length of A_{12}, starting with the known value of A_0. Measurements at this part of the spectrum are more difficult than in the more brightly illuminated portion. Three attempts, on as many different days, gave —

$$\lambda\ A_{12} = \overset{\text{m.m.}}{0.000}\ 7678.4$$
$$0.000\ 7677.8$$
$$0.000\ 7679.4$$

The mean of these $= 0.000\ 7678.5$ was taken as the value of $\lambda\ A_{12}$.

The stray light of higher refrangibility and greater illuminating power than the red, and which is reflected from the lens, overpowers the red to such an extent that some means of removing it is necessary. For this purpose, a small direct-vision prism, placed over the slit, allowing only the red to pass, seems best; but red glasses have been found to answer nearly as well.

The following are the unreduced micrometric measurements of the lines in the A group.

The numbers in each column are the original micrometric readings, which were taken consecutively without disturbance of the instrument. The different series were taken at various dates.

Beginning of A_0	5.991	6.104	1.308	1.340		1.780
End of A_0	8.295	8.352	2.843	2.880		
A_1	8.750	8.899	3.219	3.214	5.822	4.456
A_2	9.121	9.192	3.337	3.452	5.505	{ 4.759 4.900
A_3	9.459	9.595	3.608	3.700	5.144	{ 5.102 5.254
A_4	9.880	9.981	3.921	4.012	4.739	{ 5.431 5.652
A_5	10.349	10.415	4.219	4.276	4.312	{ 5.887 6.090
A_6	10.776	10.827	4.537	4.538	3.900	{ 6.350 6.523
A_7	11.284	11.323	4.861	4.848	3.425	{ 6.798 6.980
A_8	11.815	11.809	5.197	5.212	2.962	{ 7.307 7.478
A_9	12.327	12.341	5.522	5.569	2.421	{ 7.787 7.964
A_{10}	12.913	12.948	5.901	5.930	1.894	{ 8.327 8.528
A_{11}	13.495	13.490	6.238	6.282	1.393	{ 8.891 9.046
A_{12}	14.071	14.090	6.700	6.650	0.747	{ 9.424 9.587
	14.604	14.682			0.180	

The following are the remainders left after subtracting the micrometer reading of the line called A_0 from the readings of the other lines in the A group.

A_0		A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	
GRATING RIGHT.														
0.000	2.304	2.759	3.130	3.468	3.889	4.358	4.785	5.293	5.824	6.336	6.922	7.504	8.080	8.610
0.000	2.248	2.795	3.088	3.491	3.877	4.311	4.723	5.219	5.705	6.237	6.844	7.386	7.986	8.578
0.000	2.288	2.771			3.795		4.740		5.805		6.761		7.932	8.274
0.000		2.690	3.007	3.368	3.773	4.200	4.612	5.087	5.550	6.091	6.618	7.119	7.765	
0.000		2.676	3.050	3.398	3.761	4.208	4.657	5.109	5.612	6.094	6.647	7.188	7.726	
GRATING LEFT.														
0.000	1.535	1.911	2.029	2.300	2.613	2.911	3.229	3.553	3.889	4.214	4.593	4.930	5.392	
0.000	1.540	1.874	2.112	2.360	2.672	2.936	3.198	3.508	3.872	4.229	4.590	4.942	5.310	

Then follow the quotients obtained by dividing each of the numbers in the preceding table by the difference between the micrometer readings of A_0 and A_{12}.

GRATING RIGHT.

	A_0		A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}
	0.0000	0.2851	0.3415	0.3874	0.4292	0.4813	0.5394	0.5922	0.6551	0.7208	0.7842	0.8567	0.9287	1.0000
	0.0000	0.2815	0.3500	0.3867	0.4371	0.4855	0.5398	0.5914	0.6535	0.7144	0.7810	0.8570	0.9249	1.0000
	0.0000	0.2885	0.3493			0.4784		0.5976		0.7318		0.8524		1.0000
	0.0000		0.3464	0.3873	0.4337	0.4859	0.5409	0.5940	0.6551	0.7148	0.7844	0.8523	0.9168	1.0000
	0.0000		0.3464	0.3948	0.4398	0.4868	0.5448	0.6028	0.6613	0.7264	0.7888	0.8604	0.9304	1.0000

GRATING LEFT.

	0.0000	0.2900	0.3529	0.3977	0.4445	0.5032	0.5529	0.6023	0.6607	0.7292	0.7964	0.8644	0.9307	1.0000
	0.0000	0.2847	0.3544	0.3763	0.4266	0.4846	0.5399	0.5989	0.6590	0.7213	0.7815	0.8518	0.9143	1.0000

The mean of the above numbers is given in the next line:—

Mean value A_0 to $A_{12} = 1$	0.0000	0.2860	0.3487	0.3884	0.4351	0.4865	0.5429	0.5970	0.6574	0.7227	0.7860	0.8564	0.9243	1.0000

Multiplying the means by 77.6^{-10}_{m}, and adding the results to 7600.9^{-10}_{m}, we get—

Mean val. $^{-10}_{m}$ $\times$ 77.6	00.00	22.20	27.07	30.14	33.77	37.75	42.13	46.34	51.03	56.08	60.99	66.46	71.73	77.60
Last + λA_0	7600.9	7623.1	7628.0	7631.0	7634.7	7638.6	7643.0	7647.2	7651.9	7657.0	7661.9	7667.4	7672.6	7678.5

The last line gives the values of the members of the A group in wave-length.

The following are micrometric measures of the very close lines (17 in number) composing the B_0 band.

They have been distinguished by small letters of the alphabet (a to q).

B_0 group.				
a	0.897	0.876	0.298	0.296
b	0.923	0.906	0.320	0.319
c	0.990	0.976	0.365	0.382
d	1.042	1.019	0.412	0.400
e	1.082	1.070	0.471	0.465
f	1.171	1.168	0.548	0.560
g	1.263	1.260	0.669	0.648
h	1.309	1.303	0.690	0.700
i	1.399	1.387	0.779	0.780
j	1.444	1.423	0.834	0.825
k	1.540	1.518	0.926	0.920
l	1.628	1.607	1.008	1.000
m	1.709	1.710	1.115	1.103
n	1.825	1.826	1.222	1.217
o	1.923	1.908	1.301	1.306
p	2.043	2.040	1.425	1.438
q	2.156	2.146	1.543	1.536
B_1 . . .	. . . .	. . . .	1.910	1.909
B_{12} . . .	. . . .	. . . .	6.403	6.385

The following are the unreduced measurements of the principal lines in the B group:—

B_0 *a*	16.379	3.949	3.953	6.537	6.529
B_0 *q*	15.131	5.198	5.200		
B_1	14.749	5.575	5.554	8.172	8.168
B_2	14.559 14.468	5.818	5.807	8.367 8.440	8.340 8.436
B_3	14.243 14.139	6.134	6.125	8.662 8.758	8.666 8.764
B_4	13.896 13.818	6.440	6.444	8.997 9.100	8.997 9.117
B_5	13.549 13.454	6.807	6.815	9.369 9.455	9.350 9.450
B_6	13.162 13.067	7.187	7.190	9.746 9.854	9.711 9.820
B_7	12.741 12.652	7.595	7.598	10.164 10.265	10.150 10.228
B_8	12.322 12.216	8.044	8.038	10.584 10.650	10.559 10.664
B_9	11.849 11.760 11.725	8.490	8.478	11.076 11.150	11.065 11.140
B_{10}	11.404 11.315	8.961	8.957	11.522 11.628	11.528 11.596
B_{11}	10.909 10.836	9.439	9.440	12.012 12.100	12.010 12.085
B_{12}	10.292	10.013	10.032	12.624	12.616
Sharp line,	9.890				
Centre faint pair,	9.451				
Delicate pair, (1)	9.307				
Delicate pair, (2)	9.253				
Faint line,	9.049				
Faint line,	8.883				
Very faint line,	8.735				
Strong line,	8.516				
Strong line,	7.600				
End of group,	7.141				

The following are the remainders left after subtracting the micrometer reading of the line called B_0 from the readings of the other lines in the B_0 band:—

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*
0.000	.026	.093	.145	.185	.274	.366	.412	.502	.547	.643	.731	.812	.928	1.026	1.146	1.259
0.000	.030	.100	.143	.194	.292	.384	.427	.511	.547	.642	.731	.834	.950	1.032	1.164	1.270
0.000	.022	.067	.114	.173	.250	.371	.392	.481	.536	.628	.710	.817	.924	1.003	1.127	1.245
0.000	.023	.086	.104	.169	.264	.352	.404	.484	.529	.624	.704	.807	.921	1.010	1.142	1.240

Then come the quotients obtained by dividing each of the above numbers by the difference between the micrometer readings of B_0 and B_{12}.

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*
0.0000	0.0042	0.0151	0.0236	0.0301	0.0446	0.0594	0.0670	0.0817	0.0890	0.1051	0.1190	0.1321	0.1510	0.1669	0.1865	0.2048
0.0000	0.0049	0.0163	0.0233	0.0316	0.0474	0.0625	0.0695	0.0830	0.0890	0.1049	0.1190	0.1357	0.1545	0.1679	0.1894	0.2066
0.0000	0.0036	0.0110	0.0187	0.0284	0.0410	0.0609	0.0643	0.0789	0.0879	0.1030	0.1165	0.1340	0.1516	0.1644	0.1848	0.2042
0.0000	0.0038	0.0141	0.0171	0.0277	0.0433	0.0577	0.0663	0.0794	0.0868	0.1023	0.1154	0.1323	0.1511	0.1657	0.1874	0.2033

Below are the numbers obtained by subtracting the reading of B_0 from that of the other lines in the B group: —

B_0 (*a*)	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	Sharp line.	Strong line.	Strong line.	End of group.
0.000	1.630	1.865	2.188	2.522	2.878	3.265	3.683	4.110	4.583	5.020	5.507	6.087	6.489	7.863	8.779	9.238
0.000	1.626	1.869	2.185	2.491	2.858	3.238	3.646	4.095	4.541	5.012	5.490	6.064				
0.000	1.601	1.854	2.172	2.491	2.862	3.237	3.645	4.085	4.525	5.004	5.487	6.079				
0.000	1.635	1.866	2.193	2.511	2.875	3.263	3.677	4.080	4.576	5.038	5.519	6.087				
0.000	1.639	1.859	2.186	2.528	2.871	3.236	3.660	4.082	4.575	5.033	5.518	6.087				

These numbers, divided by the difference between the readings of B_0 and B_{12}, give the next.

B_0 (*a*)	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	Sharp line.	Strong line.	Strong line.	End of group.
0.0000	0.2678	0.3064	0.3595	0.4143	0.4729	0.5364	0.6050	0.6751	0.7530	0.8247	0.9046	1.0000	1.066	1.292	1.442	1.518
0.0000	0.2681	0.3082	0.3603	0.4108	0.4712	0.5339	0.6012	0.6751	0.7484	0.8264	0.9053	1.0000				
0.0000	0.2634	0.3050	0.3574	0.4099	0.4709	0.5325	0.5996	0.6705	0.7444	0.8231	0.9028	1.0000				
0.0000	0.2686	0.3066	0.3602	0.4126	0.4724	0.5360	0.6040	0.6704	0.7518	0.8277	0.9067	1.0000				
0.0000	0.2693	0.3054	0.3591	0.4154	0.4718	0.5316	0.6013	0.6707	0.7516	0.8269	0.9065	1.0000				

The measured intervals between the components of pairs, treated in the same way, become —

B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9 Triples.		B_{10}	B_{11}
0.091	0.104	0.078	0.095	0.095	0.089	0.106	0.089	0.035	0.089	0.073
0.073	0.096	0.103	0.086	0.108	0.101	0.066	0.074		0.106	0.088
0.096	0.098	0.120	0.100	0.109	0.078	0.105	0.075		0.068	0.075
These on the scale of B_0 to $B_{12} = 1$ are next given —										
0.0150	0.0171	0.0128	0.0156	0.0156	0.0146	0.0174	0.0146	0.0058	0.0146	0.0120
0.0120	0.0158	0.0169	0.0141	0.0177	0.0166	0.0108	0.0122		0.0174	0.0145
0.0158	0.0161	0.0197	0.0164	0.0179	0.0128	0.0173	0.0123		0.0112	0.0123
The means of the intervals are —										
.0143	.0163	.0165	.0154	.0171	.0147	.0152	.0130		.0144	.0129

The first line in the following table gives the value of the components of the B group on the scale B_0 to $B_{12} = 1$. The difference of wave-length corresponding to this interval is 61 tenth meters, and the numbers in the second line are obtained by multiplying those in the first by 61.

	B_0 a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
Mean value, B_0 to $B_{12} = 1$	0.0000	0.0041	0.0141	0.0207	0.0295	0.0441	0.0601	0.0668	0.0808	0.0882	0.1038	0.1175	0 1335	0.1521	0.1665	0.1856	0.2047
Mean val. $\times 61^{-10}$ m	00.00	00.25	00.86	01.26	01 80	02.69	03.67	04.07	04.93	05 38	06.33	07.17	08.14	09.28	10.16	11.32	12.49
Last + λB_0	6866.8	6867.0	6867.7	6868.1	6868.6	6869.5	6870.5	6870.9	6871.7	6872 2	6873.1	6874.0	6874.9	6876.1	6877.0	6878.1	6879.3

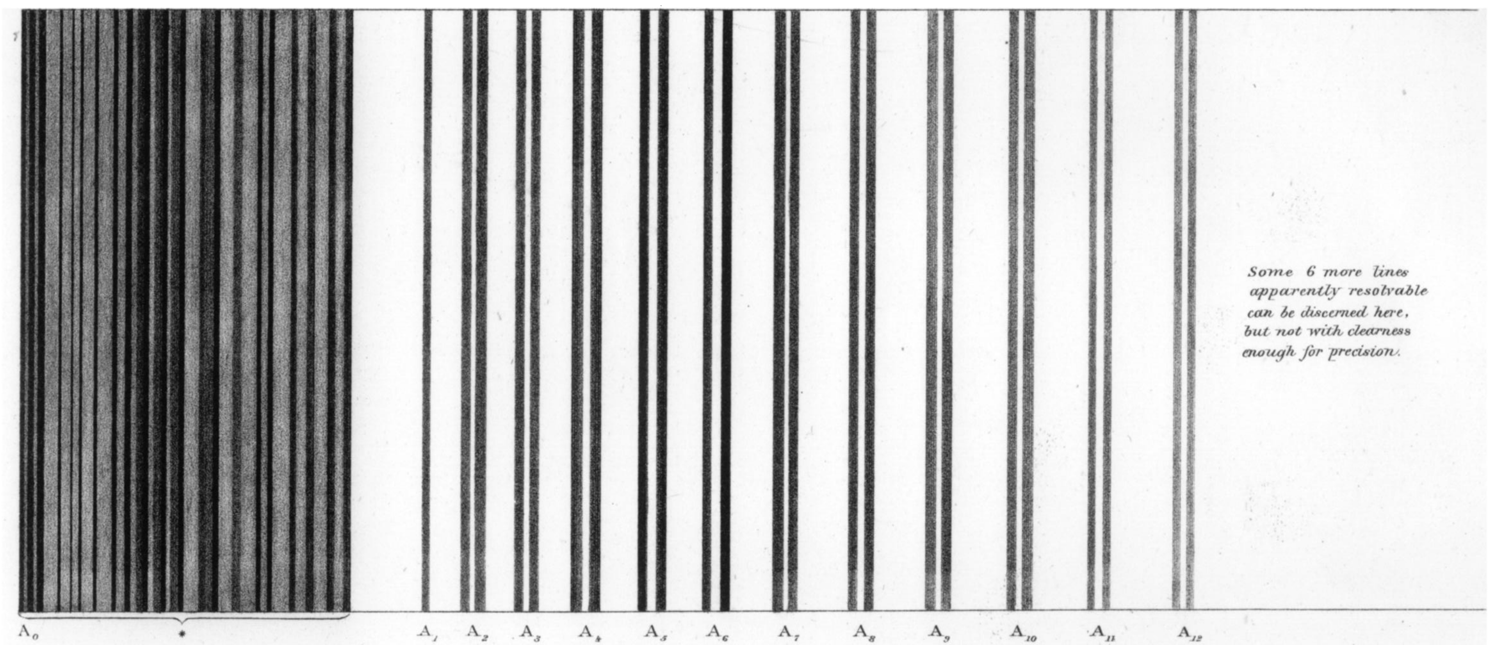
After these operations, the products in line two being added to the wave-length of B_0 give the final *wave-lengths* contained in line three.

	B_0	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	Sharp line.	Strong line.	Strong line.	End of group.
Mean value, B_0 to $B_{12} = 1$	0.0000	0.2674	0.3063	0.3593	0.4126	0.4718	0.5341	0.6022	0.6724	0 7498	0.8258	0.9052	1.0000	1.066	1.292	1.442	1.518
Mean val. $\times 61^{-10}$ m	00.00	16.31	18.68	21.92	25.17	28.78	32.58	36.73	41.02	45.74	50 37	55.22	61 00	65.03	78.71	87.96	92.60
Last + λB_0	6866.8	6883.1	6885.5	6888.7	6892.0	6895.6	6899.4	6903.5	6907.8	6912.5	6917.2	6922.0	6927.8				

Mean interval between components of pairs = 0.0150 (B_0 to $B_{12} = 1.$)

In wave-lengths " " " " " $= 00.92^{-10}$ m

"A" GROUP

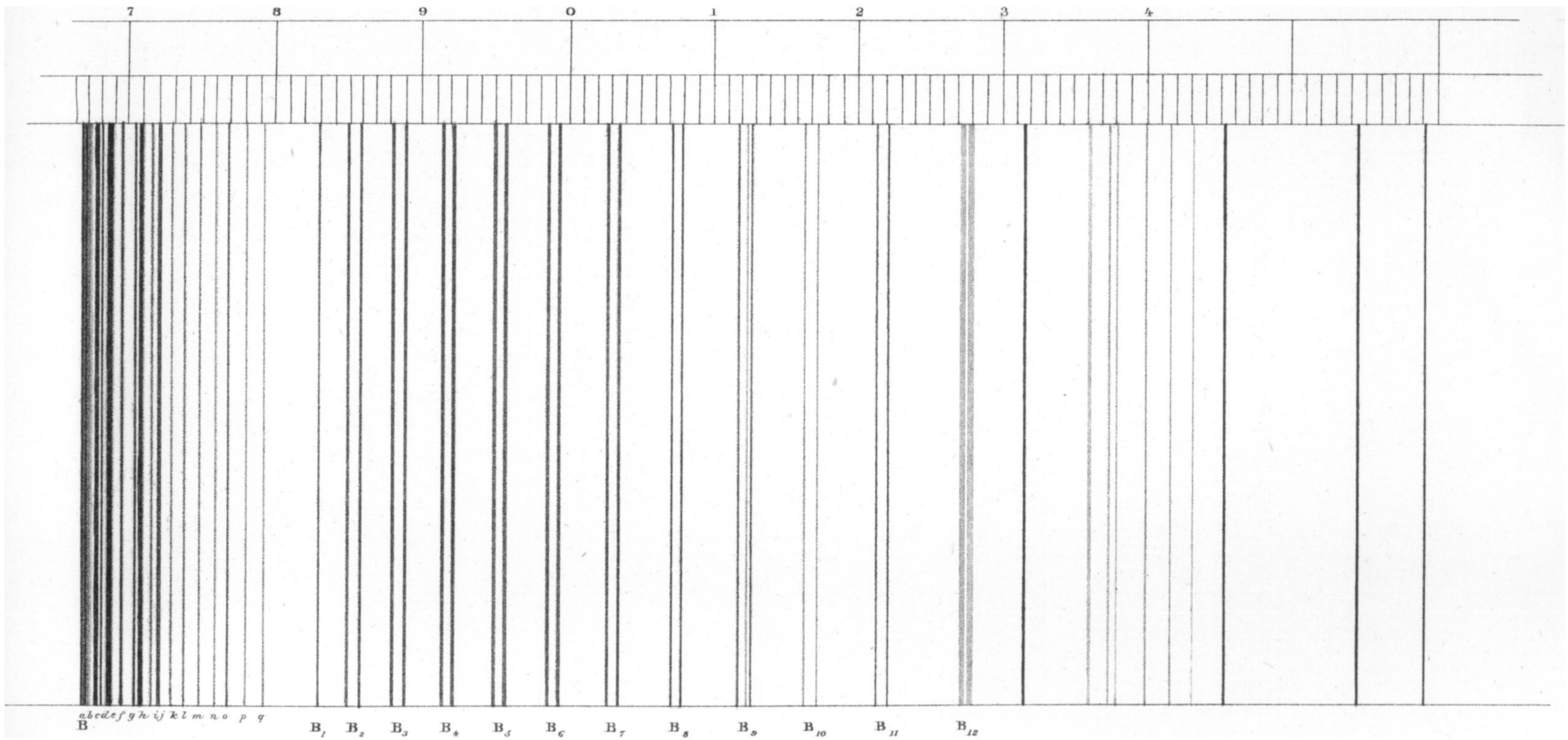


* Note: the position of some of the lines in this wide band is uncertain, on account of the darkness of the field. It is not clear, how far the greater apparent width of the lines in the pairs than in those of "B" is real, and how far due to the need of a very wide slit.

S. P. Langley.
Alleg.y Obs.y Oct. 10. 78.

For Rumford Paper.

"B" GROUP

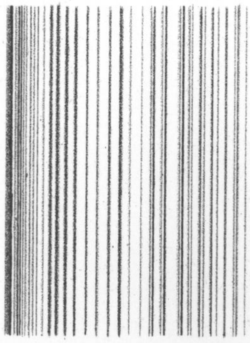


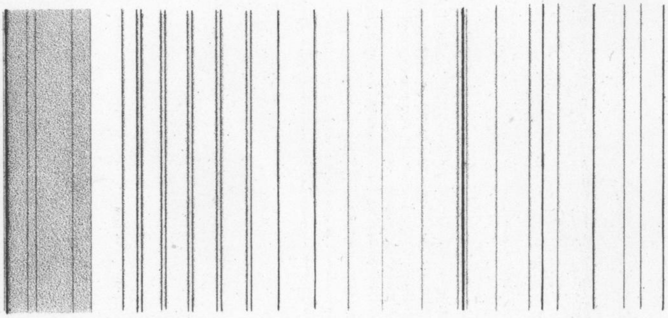
For Rumford Paper.

S. P. Langley.
Alleg.^y Obs.^y Oct.^r 10. 78.

FROM KIRCHOFF'S CHART.

"B" Group

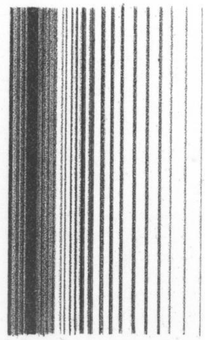


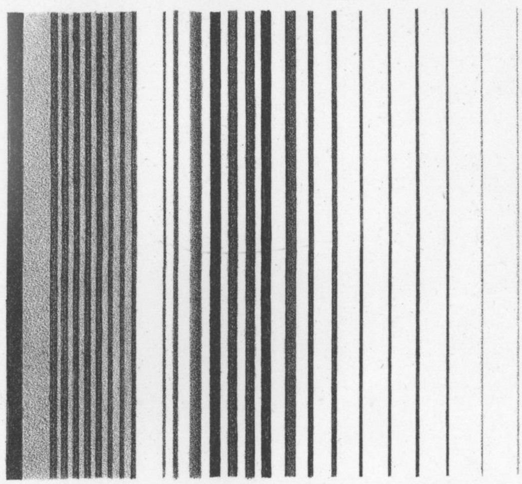


"B" Group *From Angstrom.*

OM KIRCHOFF'S CHART.

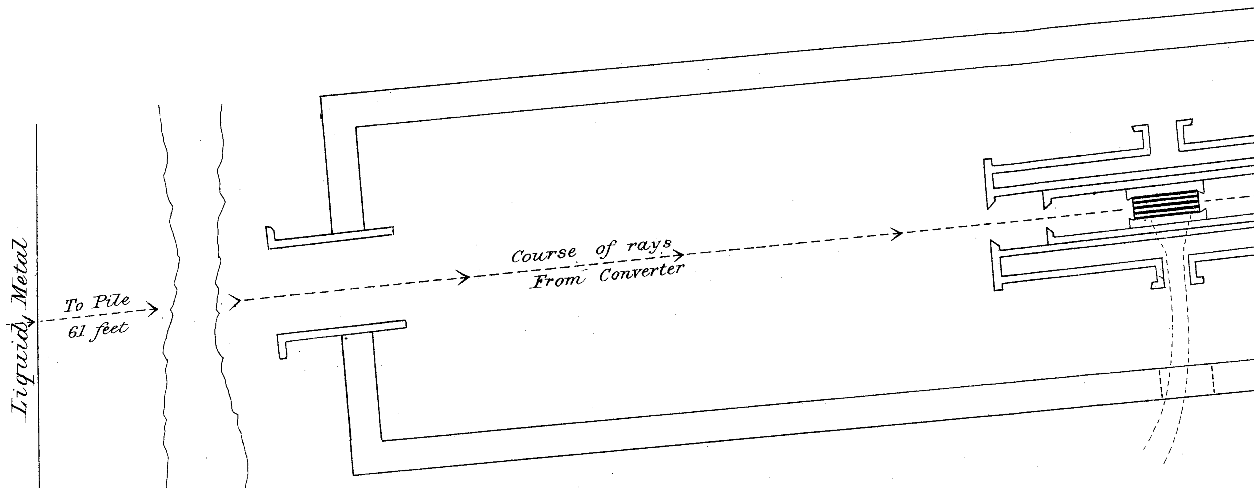
"A" Group





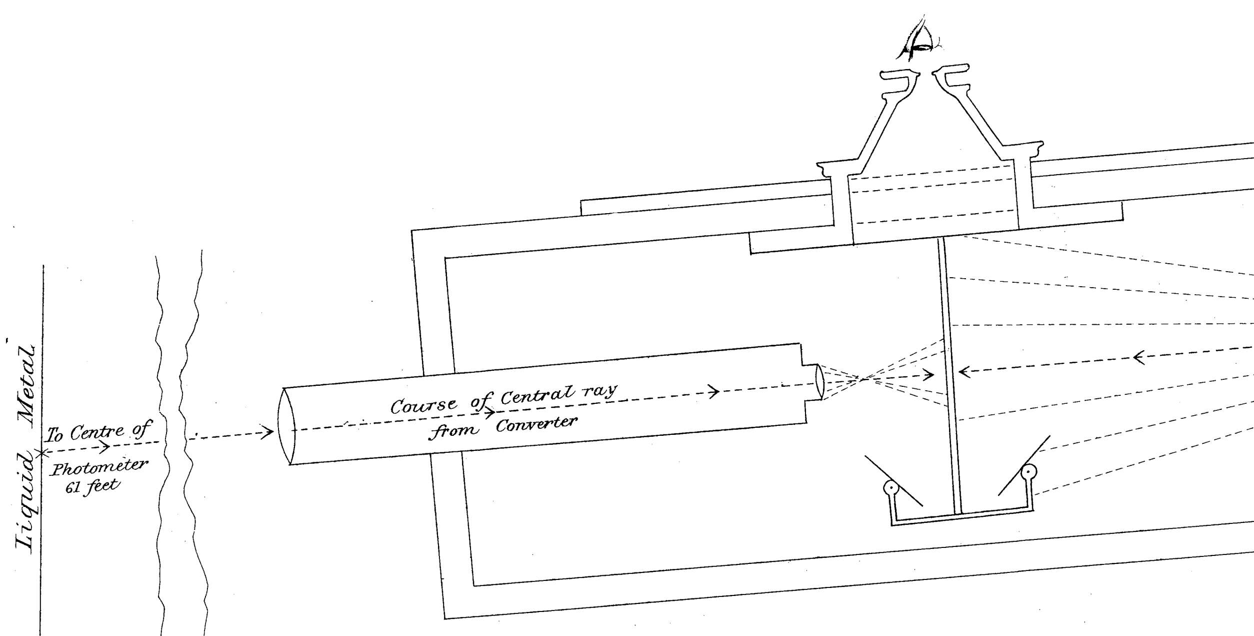
"A" Group   *From Smythe..*

S.P. Langley
Paper on A & B lines



SKETCH 1. *Disposition of the*

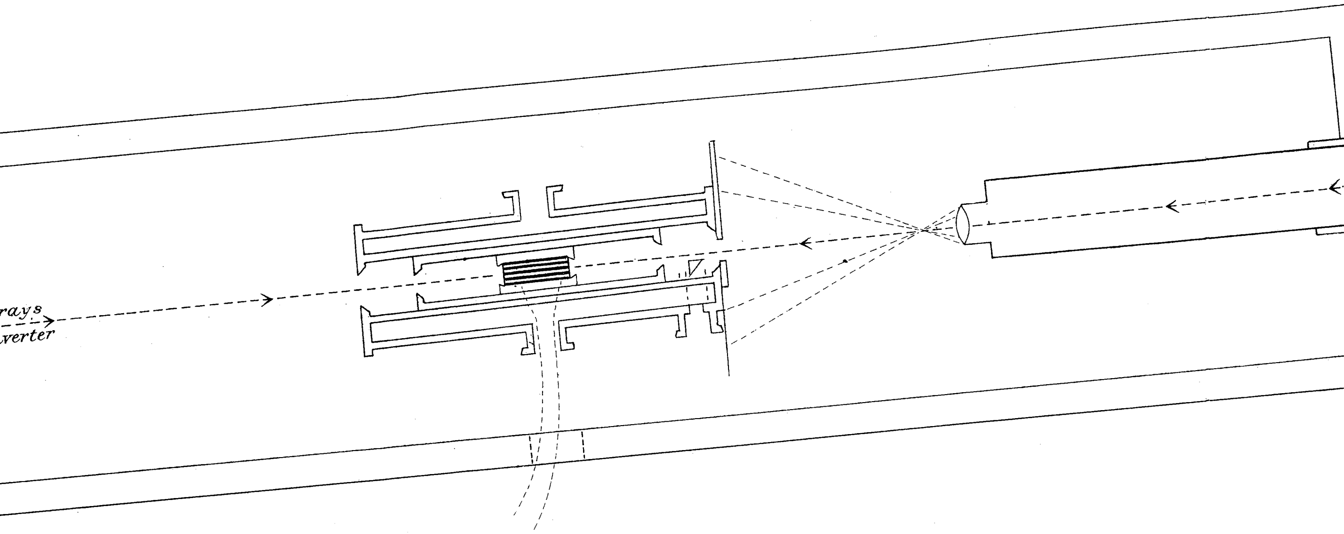
(*Not to Scale.*)



SKETCH 2. *Disposition o*

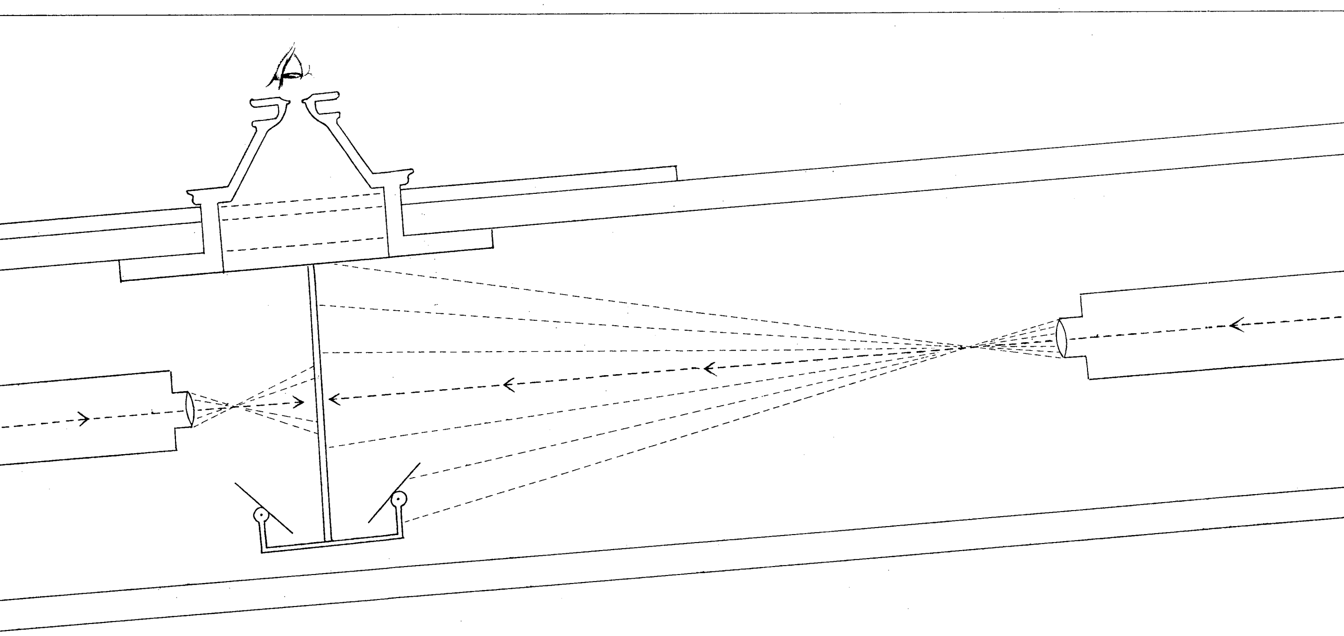
(*Not to Scale.*)

A. Meisel, lith. Boston.



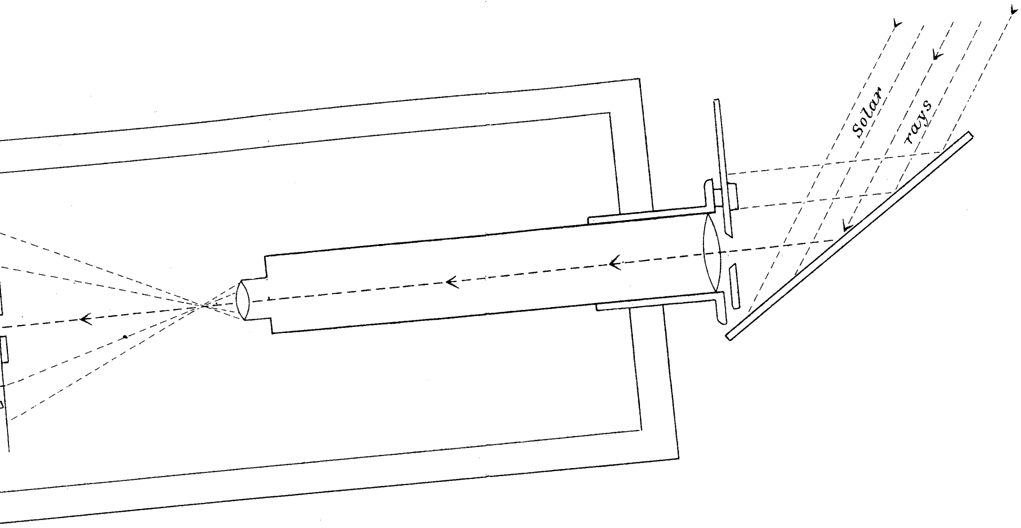
SKETCH 1. *Disposition of thermopile and heat apparatus.*

(Not to Scale.)

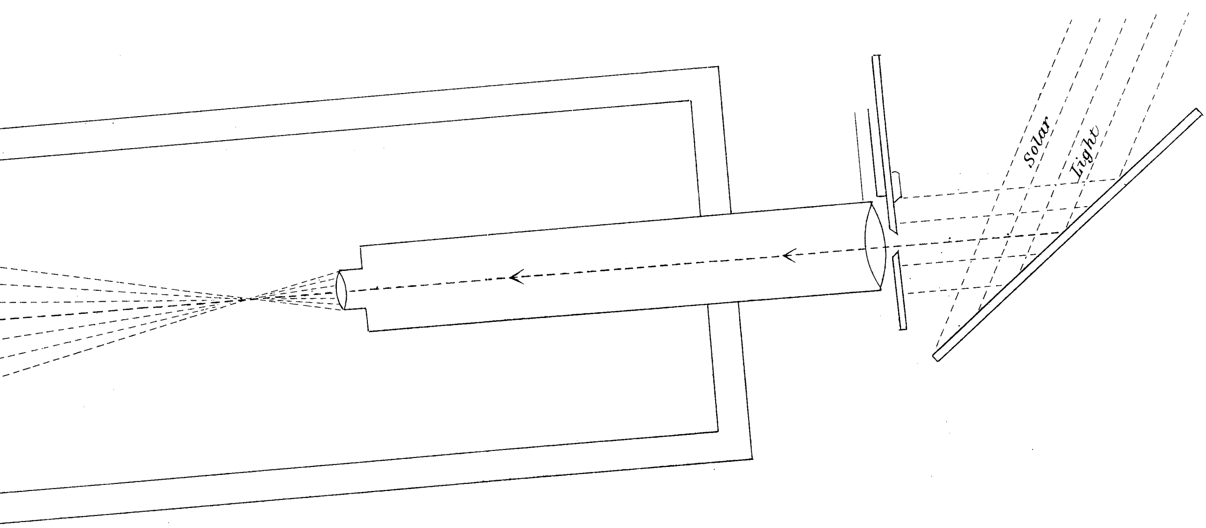


SKETCH 2. *Disposition of Bunsen Photometer with moveable screen.*

(Not to Scale.)



e and heat apparatus.



sen Photometer with moveable screen.

S. P. Langley.
Rumford Paper on
Solar Temperature.